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Design and Fabrication of Driver Amplifier for Wilkinson Power Divider Operating at S Band

Doan Huu Chuc[1,*], Bach Hoang Giang[2], Hoang Duc Long[2], Bach Gia Duong[2]

[1]*Hai Phong Private Unversity, 36 Dan Lap, Le Chan, Hai Phong, Vietnam*

[2]*University of Engineering and Technology, VNU, 144 Xuan Thuy, Hanoi, Vietnam*

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Abstract. In this paper, we introduce an overview of microwave power transmission system (MPT) including of power transmitter, free space transmission, rectenna. Also, the paper particularly presents in detail the proposed configuration of power transmitter. The presented power amplifier, which has the output of 1W, is fabricated by using AH201. The 1-Watt amplifier plays an important role as driver amplifier in the configuration. In addtion, the 4 – way Wilkinson divider/combiner has been designed and manufactured. All simulations and experimental results will be reported.

Keywords: Power amplifier, Wilkinson power divider.

1. Introduction

William C. Brown, the pioneer in wireless power transmission technology, has designed, developed a unit and demonstrated to show how power can be transferred through free space by microwaves. The concept of Microwave Power Transmission (MPT) System is explained with functional block diagram shown in Fig 1. In the transmission side, the microwave power source generates microwave power and the output power is controlled by electronic control circuits. The transmitting antenna radiates the power uniformly through free space to the rectenna. In the receiving side, the rectenna receives the transmitted power and converts the microwave power into DC power [1].

The transmitter of the microwave power transmission system is of especially important. It could be seen as the key to successful implementation of the MPT system. The block diagram of the transmission used for MPT is shown in Fig 2. In fact, it is necessary for the signal from an oscillation amplified by a power amplifier (PA) before it is to get a high power for antenna system. Furthermore, this power amplifier has a function for impedance matching between the signal generator oscillator (Osc) and power divider. The power division is usually the Wilkinson power divider. Output ports of

* Corresponding author. Tel.: 84-904513379
Email: chucdh@hpu.edu.vn

the power divider are fed to next power amplifier modules. The power of PAs will be combined by a power combiner as the Wilkinson combiner before they are transmitted.

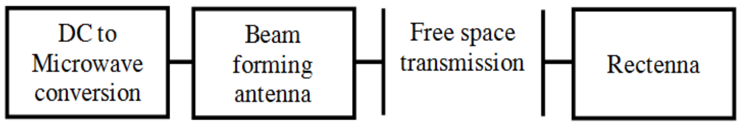


Fig 1. Block diagram of MPT.

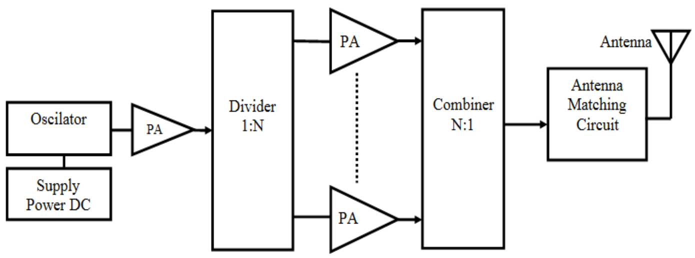


Fig 2. Block diagram of a transmitter for MPT system.

2. Design of the Power Amplifier

The typical diagram of a microwave power amplifier is shown in Fig 3. We use the two – ports network as mentioned in [2] to design power amplifier in terms of S-parameter of RF transistor.

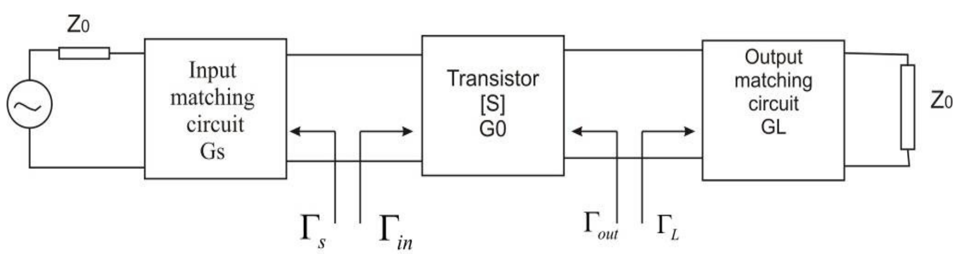


Fig 3. The typical diagram of amplifier circuit.

In the microwave field, standard circuit theory generally cannot be used directly to solve microwave network problems. In a sense, standard circuit theory is an approximation of electromagnetics as described by Maxwell's equations [2,3]. This means that the procedure for microwave design absolutely differs from the one at lower frequencies. This is so-called impedance matching technique. In general, there are many based-on-Smith-chart matching approaches introduced in detail in [2] such as, lumped matching network, micro-strip matching network, etc. The advantages of CAD software supported by Agilent Technology make it easier to design, optimize, and enhance the time-to-market.

In this case, the medium power and high-linearity amplifier AH201 was selected to design and manufacture the power amplifier to be used for Wilkinson power divider. This is a 1W driver amplifier, wide operating frequency ranging up to 3GHz [4]. All design and simulations are achieved using ADS2009 package. The schematic of the power amplifier is shown in Fig 4. In this circuit, the elements of C2, L1 are used for input matching network and the remaining of L2, C3, C4 are used for output matching one. Moreover, the simulated inductor L2 is of radio frequency choke (RFC). The circuit is simulated in double-sided FR4 (Dielectric constant = 4.34, Height =1.6 mm, Thickness= 0.035mm) and power supply 11VDC.

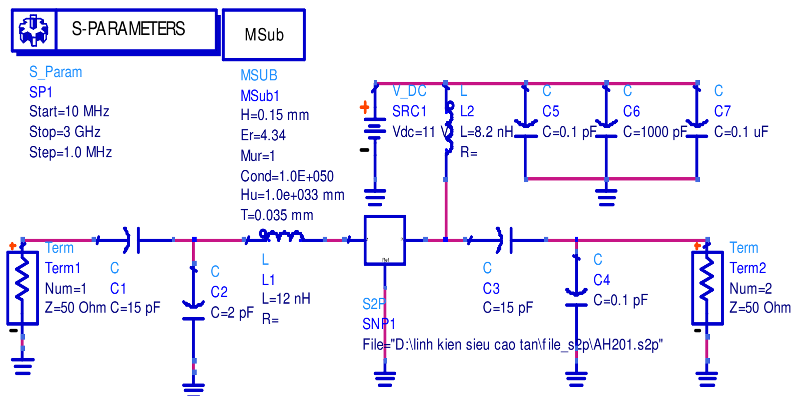
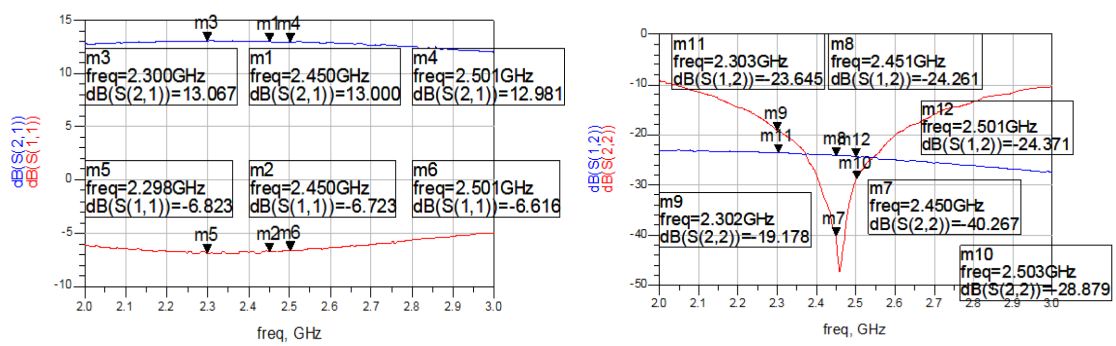


Fig 4. Schematic of power amplifier.

The simulated results of the amplifier are figured out in Figure 5(a, b). In Fig 5.a, the gain of amplifier is 13dB over the range of 2 GHz to 2.8 GHz meeting the required specification for such a system. However, the input reflection coefficient is smaller -6dB over the same frequency band. This is wide-band driver amplifier having the output power of 1W. The Fig 5.b shows that the value of the output reflection coefficient is well below -10dB, which means that perfect matching is performed over the band from 2.2GHz to 2.8GHz. The values at marker 8, 11, 12 illustrates that the driver amplifier has high-isolation characteristic being over -23dB. According to the above results, the presented amplifier could absolutely satisfy the parameter in terms of a driver amplifier as well as buffer amplifier.



a. b.

Fig 5. The simulation results of the driver amplifier;
a. The simulated S11 and S21; b. The simulated S12 and S22.

Aftermaths, the layout of the circuit is designed and fabricated using the LPKF C40 in Fig 6. To design power amplifier, we find that it is necessary to analyze the frequency response of the amplifier whether it works or not by using the Vector Network Analyzer 37369D (40MHz- 40GHz). This step will help the designer analyze or even directly optimize the design. Another problem must be paid attention is that cooling for power transistor to guarantee the operating condition. In this design, it could be seen in Fig 6.b. Such an amplifier is working properly at 11VDC @330mA, class AB.

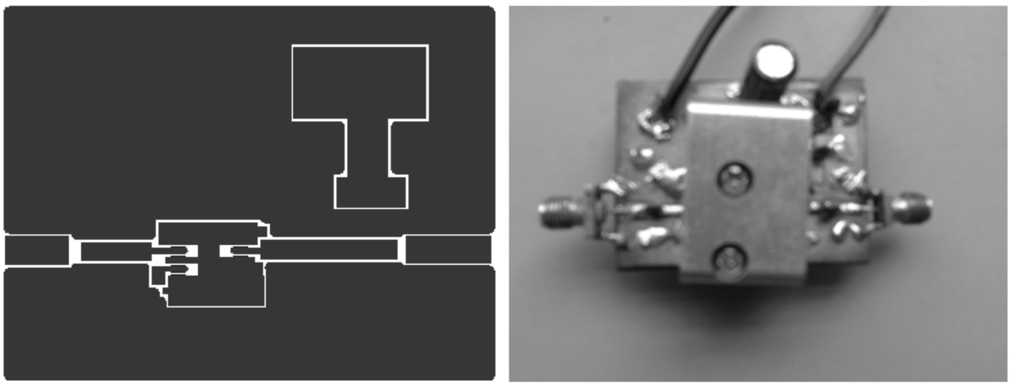
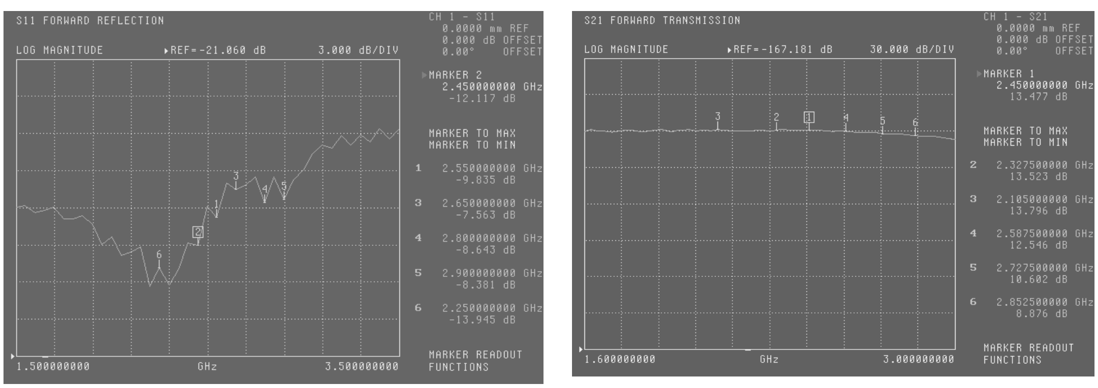


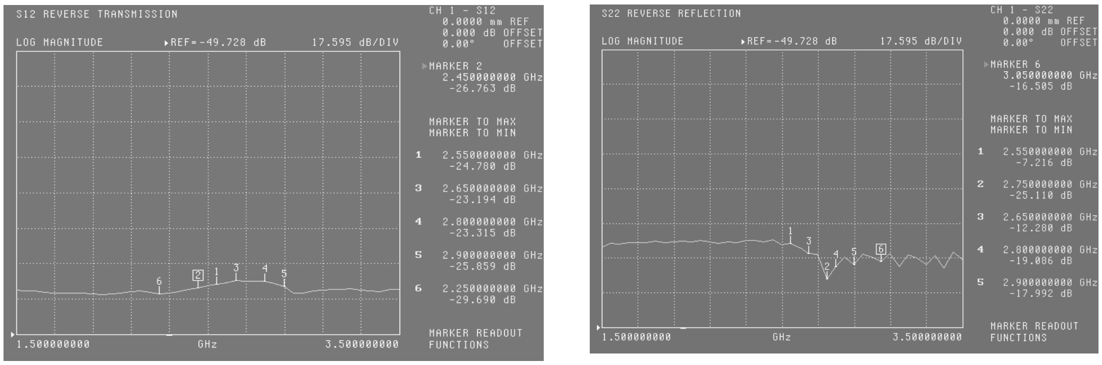
Fig 6. a. Layout of the power amplifier; b. The fabrication of the amplifier.



a b.

Fig 7. a. The experimental value of S11; b. The experimental value of S21.

The value of S11 and S21 are shown in Fig 7. It can be seen that the input return loss is smaller 7dB (especially 12dB at 2.45GHz) meaning that the quite good matching is performed over the range of 2 GHz to 2.7GHz. The measured S21 (gain of the amplifier) is well above 13dB in comparison with the ideal value of AH201A. The other crucial characteristics that must be performed are the value of S12 and S22 respectively. The Fig 8.a illustrates that the result of S12 is closely equal to the simulated one (-22dB) and the output return loss is smaller 7dB for the output matching requirement of the amplifier.



a b.

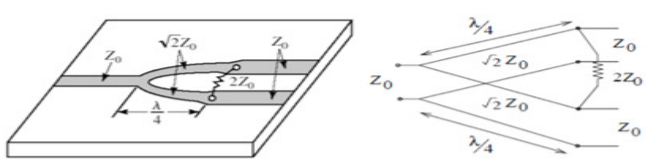
Fig 8. a. The experimental value of S12; b. The experimental value of S22.

Table 1. The comparison of simulated results and experimental ones at 2.5GHz

Parameter (at 2.45GHz)	The simulated results	The measured results
S11	**-6.7dB**	**-10dB**
S22	**< -15dB**	**< -12dB**
S12	**-22dB**	**-25dB**
S21	**13dB**	**13.47dB**

3. Wilkinson power divider

The 2-way WPD usually employs quarter-wavelength transmission line λ/4 section at the design center frequency and Wilkinson power consists of two quarter -wavelength line segments at the center frequency with characteristic impedance $\sqrt{2}$*Zo, and a 2*Zo lumped resistor connected between the output ports. A popular basic configuration of the 2-way WPD is often made in micro-strip or strip-line form as depicted in Fig 9.a, and the corresponding transmission line circuit is given in Fig 9.b [5,6,7].



a. b.

Fig 9. The Wilkinson Power Divider.
a. An equal-split Wilkinson power divider in microstrip form.b. Equivalent transmission line circuit.

In this part, a 4-way Wilkinson power divider with a center frequency of 2.45 GHz matched to 50-Ω transmission line was designed and fabricated. The circuit was designed and optimized using Advance Design System (ADS), then fabricated using micro-strip lines with a FR4 substrate. The circuit was later observed with the Anritsu 37369D Vector Network Analyzer, and these experimental results were compared with the ADS simulation.

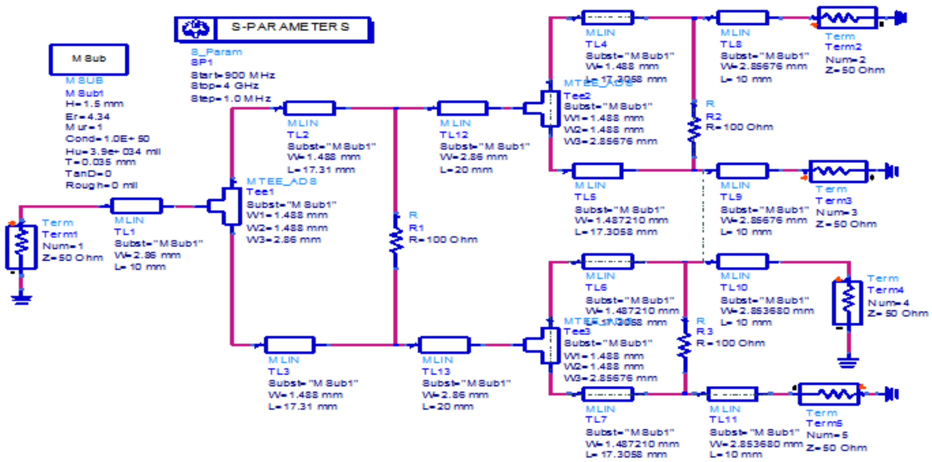


Fig 10. Schematic of 4 – way WPD.

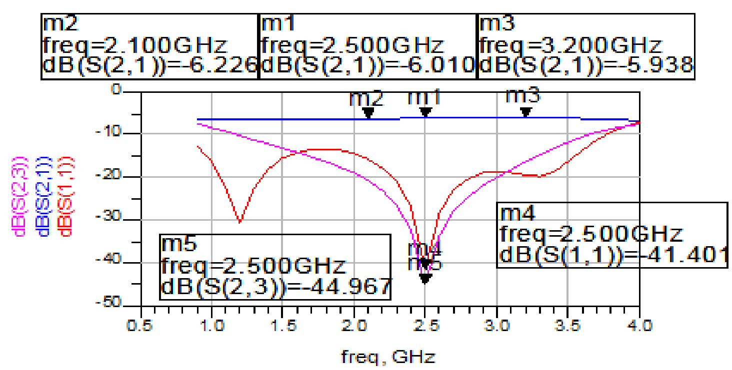
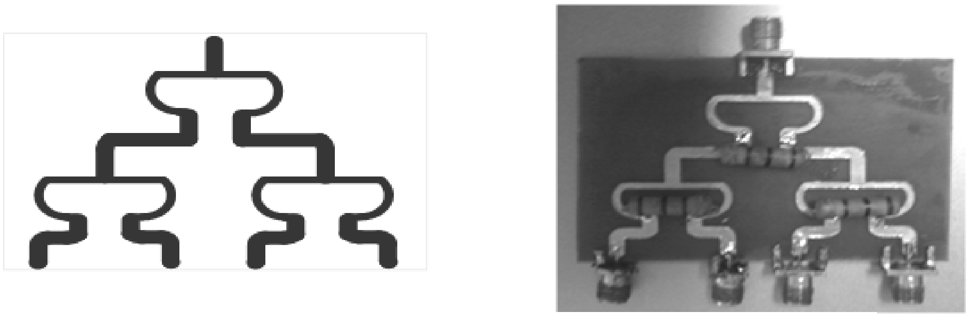


Fig 11. The simulated results.

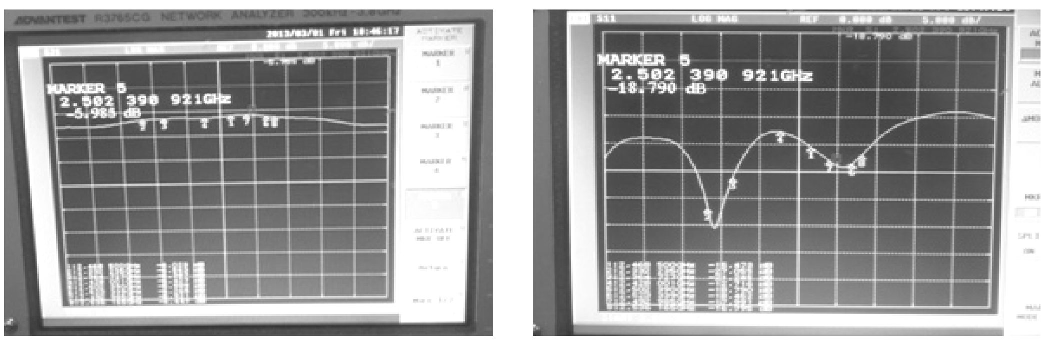
In the Fig 11, it could be figured out that the transmission coefficient is good matching being less than -41 dB over the center frequency. The simulated transmission coefficient's attenuation is equal to -6.01dB, being nearly close to the theoretical one. The achieved results totally satisfy the given criteria about loss, bandwidth, VSWR, and 50Ω matching requirement.

The value S21 and S11 of Wilkinson power divider are given in Fig 11. According to S21< -6 dB in the range of 2.4 GHz to 2.5 GHz band, which is better than results with values obtained in the simulation. The value of S11 is equal to -18.79 dB at 2.5 GHz frequency, which means that the impedance matching is very good.



a. b.

Fig 12. a. Layout; b. Fabrication of 4- way WPD.



a. b.

Fig 13. Measurement results. a. S21; b. S11.

The fabricated power amplifier is used to amplify the signal from OSC before being feeding into the Wilkinson power divider. Output ports of WPD are amplified by next PA modules as described in Fig 1. The gain is over 13 dB operating at 2.4 GHz – 2.5GHz band. Other parameters are met for a signal generator circuit for in proposed configuration.

4. Conclusion

The proposed configuration of the power transmitter, which is used for the MPT system, is presented. Such a configuration is based on the power combination method including of 1W power amplifier, 4-way Wilkinson bridge and a number of high power amplifiers. The described design of driver amplifier as well as 4-way in-phase combiner would be realized as the fundamental step for such a system. The research will be the breakthrough for the design of MPT system especially in Vietnam.

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